Statistical Models for Mechanical Properties of Basalt Fibre Reinforced Concrete

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Abstract- In the present study, strength properties of concrete reinforced with basalt fibres are examined and statistical models are developed to establish the relation between the strength parameters. Optimum length and dosage of bundles and filament basalt fibres is decided from lengths 12 mm, 36mm and 50mm and dosage of 0.2%, 0.3% and 0.4% fibre fraction by volume of concrete. This optimum dosage of and length combinations for bundled and filament fibres yield increase in compressive, split-tensile and flexural strength by……%

I. INTRODUCTION

Concrete subjected to tensile stresses develops cracks in the tensile zone which can be controlled by use of steel reinforcement. But micro and macro cracks can be prevented by the use of fibres in concrete. Fibres also enhance mechanical properties other than crack controlling. Fibres like nylon, polypropylene has low modulus of elasticity than that of matrix, high elongation property, don't impart strength but has improved toughness, impact resistance and resistance to explosive loads. Steel, carbon and glass fibre will have high modulus of elasticity, high strength and stiffness. Concrete made with low fibre volume (less than 1%) will be used to reduce shrinkage cracking, concrete made with moderate fibre volume (less than 2%) will improve mechanical properties such as flexural strength, toughness and impact resistance. Basalt fibre has high tensile strength, non-corrosive, bad conductor of electricity, good thermal and chemical resistant. Density of basalt fibre = 2600-2700 kg/m^3. Concrete made with high fibre volume (more than 2%) has improved strain hardening. Long fibres will reduce the workability of the concrete mix. Volume of long fibre required will be less than short fibre. Fibres with l/d ratio less than 50 will scatter easily in the concrete mix. Fibres with l/d ratio more than 100, are likely to interlock. In matrix having large aggregates there is tendency of lumping of fibres around large aggregates.

II. OBJECTIVES

1. To choose the optimum length of fibre and dosage of bundled basalt fibres and basalt filaments for optimum performance
2. To study the effect of basalt fibres on compressive strength, split tensile strength and the flexural strength of basalt fibre reinforced concrete.
3. To establish empirical relation of parameters such as split-tensile strength, flexural strength with compressive strength.

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III. EXPERIMENTAL INVESTIGATIONS

To assess the mechanical properties of basalt fibre reinforced concrete experimentally, the following investigations are done.

1. Dosage of basalt fibre
2. Compressive strength
3. Split-tensile strength
4. Flexural strength
5. Statistical Modelling

In this study an optimum dosage of basalt fibres of type filaments (ϕ=16μ) and bundles with various lengths (12mm/36mm/50mm) is decided upon for a plain concrete mix of M30 grade. During mixing filament fibres with length more than 36 mm forms lumps at higher dosage of 0.3% and 0.4% by volume of concrete. To prevent lumping the fibres are added slowly to the dry mix in the concrete mixer at a constant rate. The bundled fibres usually gets separated and distributed uniformly as individual filaments in the concrete mix.

As the length of basalt fibres increases slump values decreases for both filament and bundle types. Slump of 100 to200mm is desired to achieve. In high dosage and high length chopped basalt fibres slump values are less than 100mm so SP is used.

Table 1- Slump values and Compressive strengths of bundled and filament basalt fibre reinforced concrete mixes

Basalt Type	Designation	Length of fibre (mm)	Dosage percentage by volume of concrete	Slump (mm)	Compressive Strength (MPa)
Plain Concrete	PC	0	0	100	39.12
Basalt Filament	BF1	12	0.2%	195	40.19
	BF2	12	0.3%	152	41.24
	BF3	12	0.4%	173	43.15
	BF4	36	0.2%	210	41.57
	BF5	36	0.3%	220	43.78
	BF6	36	0.4%	200	45.23
	BF7	50	0.2%	220	44.39
	BF8	50	0.3%	225	48.55
	BF9	50	0.4%	140	40.11
Basalt Bundle	BB1	12	0.2%	181	41.40
	BB2	12	0.3%	160	42.48
	BB3	12	0.4%	143	44.44
	BB4	36	0.2%	220	42.82
	BB5	36	0.3%	180	45.09
	BB6	36	0.4%	130	46.59
	BB7	50	0.2%	153	45.72
	BB8	50	0.3%	170	50.01
	BB9	50	0.4%	146	41.31

Table 2- Split-tensile and flexural strengths of bundled and filament basalt fibre reinforced concrete mixes

Basalt Type	Designation	Length of fibre (mm)	Dosage percentage by volume of concrete	Split-tensile Strength MPa	Flexural Strength MPa
Plain Concrete	PC	0	0	2.96	3.62
Basalt Filament	BF1	12	0.2%	3.11	3.89
	BF2	12	0.3%	3.29	4.56
	BF3	12	0.4%	3.78	4.99
	BF4	36	0.2%	3.88	4.13
	BF5	36	0.3%	4.34	5.34
	BF6	36	0.4%	4.52	5.45
	BF7	50	0.2%	3.99	5.22
	BF8	50	0.3%	4.21	5.67
	BF9	50	0.4%	3.98	5.27
Basalt Bundle	BB1	12	0.2%	3.20	4.01
	BB2	12	0.3%	3.39	4.70
	BB3	12	0.4%	3.89	5.14
	BB4	36	0.2%	4.00	4.25
	BB5	36	0.3%	4.47	5.50
	BB6	36	0.4%	4.66	5.64
	BB7	50	0.2%	4.11	5.38
	BB8	50	0.3%	4.34	5.87
	BB9	50	0.4%	4.10	5.46

Fibre addition increases compressive strength of concrete, especially as length of basalt fibre increases the compressive strength increases and workability reduces gradually. Similarly as percentage dosage of fiber increases the compressive strength increases till certain percentage of fibre volume of concrete. The dosages of basalt fibre used are 0.2% (5.2 kg/m^3), 0.3% (7.8 kg/m^3) and 0.4% (10.4 kg/m^3) by volume fraction of the concrete. With increase in length and fibre dosage, workability reduced due to restriction of aggregate movement. At higher dosage mix becomes very stiff and cohesive and compressive strength is low due to ineffective distribution of fibres in concrete in the form of bunching together. The decrease in the slump values at high dosage of basalt fibre reinforced concrete is due to the large fibre surface area and the high content of fibres may require more cement paste to cover them. This consequently increases the water cement ratio.

For fibre length of 50mm and dosage of 0.3% fibre volume of the concrete, the compressive and flexural strengths attained are maximum but the flexural strength is found to be more for fibre length of 36mm and dosage of 0.4% fibre volume of the concrete.

4. EMPIRICAL EQUATIONS

This phase presents relations between split tensile strength, flexural strength in terms of compressive strength.

1) Relation between Split tensile Strength (S) and Compressive Strength (C)

Let the relationship between the split tensile strength (S) and compressive strength (C) be expressed in the form

$S= a (C)^{b}$ 1

a and b are constants

Take log on both sides of equation 1

$\log S = \log a + b \log C$ 2

$\Sigma \log S = N \log a + b\, \Sigma \log C$ 3

$\Sigma(\log C * \log S) = \log a * \Sigma \log C + b\Sigma(\log C)^2$ 4

N – No of samples considered

Solve the above equations to get

$b = [\ \Sigma\log C * \Sigma\log S - N\ \Sigma(\log C * \log S)]/[\ (\Sigma\log C)^2$ -

$N\ \Sigma(\log C)^2]$ ……..5

and

$\log a = [\Sigma \log S - b\ \Sigma \log C] / N$

or

$a = \log^{-1}[\ [\Sigma \log S - b\ \Sigma \log C] / N]$ ………6

From table 3, a = 1.0 and b = 0.35

From Equation1 we get,

$$S = C^{0.35} \quad \text{…......7}$$

Equation 7 is the proposed empirical expression for S (Theoretical) in terms of C for basalt fibre reinforced concrete.

2) Relation between Flexural strength (F) and Compressive Strength (C)

From table 4, we get

a = 1.0 and b = 0.43

we get, $F = C^{0.42}$

is the proposed empirical expression for F (Theoretical) in terms of C for basalt fibre reinforced concrete.

Table 3- Empirical expression for Split-tensile strength in terms of Compressive Strength

Designation	Split-tensile Strength MPa (T)	Compressive Strength (C)	Y=logT	X=logC	XY	X^2
PC	2.96	39.12	0.471292	1.592399	0.750484	2.535734
BF1	3.11	40.19	0.49276	1.604118	0.790446	2.573195
BF2	3.29	41.24	0.517196	1.615319	0.835436	2.609254
BF3	3.78	43.15	0.577492	1.634981	0.944188	2.673162
BF4	3.88	41.57	0.588832	1.61878	0.953189	2.620449
BF5	4.34	43.78	0.63749	1.641276	1.046296	2.693786
BF6	4.52	45.23	0.655138	1.655427	1.084534	2.740437
BF7	3.99	44.39	0.600973	1.647285	0.989974	2.713548
BF8	4.21	48.55	0.624282	1.686189	1.052658	2.843234
BF9	3.98	40.11	0.599883	1.603253	0.961764	2.570419
BB1	3.20	41.40	0.50515	1.617	0.816828	2.61469
BB2	3.39	42.48	0.5302	1.628185	0.863263	2.650985
BB3	3.89	44.44	0.58995	1.647774	0.972104	2.715159
BB4	4.00	42.82	0.60206	1.631647	0.982349	2.662271
BB5	4.47	45.09	0.650308	1.65408	1.075661	2.735981
BB6	4.66	46.59	0.668386	1.668293	1.115063	2.783201
BB7	4.11	45.72	0.613842	1.660106	1.019043	2.755953
BB8	4.34	50.01	0.63749	1.699057	1.083131	2.886794
BB9	4.10	41.31	0.612784	1.616055	0.990293	2.611634
N=18	Σ		11.17551	31.12122	18.3267	50.98989

Table 4- Empirical expression for Flexural strength in terms of Compressive strength

Designation	Flexural Strength MPa (F)	Compressive Strength (C)	Y=logT	X=logC	XY	X^2
PC	3.62	39.12	0.558709	1.592399	0.889687	2.535734
BF1	3.89	40.19	0.58995	1.604118	0.946349	2.573195
BF2	4.56	41.24	0.658965	1.615319	1.064438	2.609254
BF3	4.99	43.15	0.698101	1.634981	1.141381	2.673162
BF4	4.13	41.57	0.61595	1.61878	0.997088	2.620449
BF5	5.34	43.78	0.727541	1.641276	1.194096	2.693786
BF6	5.45	45.23	0.80956	1.655427	1.340167	2.740437
BF7	5.22	44.39	0.717671	1.647285	1.182208	2.713548
BF8	5.67	48.55	0.824126	1.686189	1.389632	2.843234
BF9	5.27	40.11	0.797268	1.603253	1.278221	2.570419
BB1	4.01	41.40	0.603144	1.617	0.975285	2.61469
BB2	4.70	42.48	0.672098	1.628185	1.094299	2.650985
BB3	5.14	44.44	0.710963	1.647774	1.171507	2.715159
BB4	4.25	42.82	0.628389	1.631647	1.025309	2.662271
BB5	5.50	45.09	0.740363	1.65408	1.224619	2.735981
BB6	5.64	46.59	0.822168	1.668293	1.371617	2.783201
BB7	5.38	45.72	0.730782	1.660106	1.213176	2.755953
BB8	5.87	50.01	0.836957	1.699057	1.422037	2.886794
BB9	5.46	41.31	0.810233	1.616055	1.30938	2.611634
N=18	Σ		13.55294	31.12122	22.2305	50.98989

IV. CONCLUSIONS

1. For fibre length of 50mm and dosage of 0.3% fibre volume of the concrete, the compressive and flexural strengths attained are maximum but the flexural strength is found to be more for fibre length of 36mm and dosage of 0.4% fibre volume of the concrete.

2. The increase in compressive, split-tensile and flexural strength of bundled basalt fibres and filament basalt fibres are almost similar.
3. The optimum length of fibre for basalt filament and bundled fibre concrete is 50 mm and dosage is 0.3% by volume of concrete for which the increase in compressive is 24% and 27% in basalt filament and bundled fibre concrete respectively
4. Flexural strength increase is 56 and 62% for basalt filament and bundle fibre concrete respectively made with optimum length of fibre of 50mm and dosage 0.3% fibre fraction by volume of concrete.
5. It is observed that flexural strength is 52% and 57% more for filament and bundled basalt concrete made with 36mm length fibre and for dosage of 0.4% fibre fraction volume of concrete.
6. Relation between Split tensile Strength (S) and Compressive Strength (C) is $S = C^{0.35}$
7. Relation between Flexural strength (F) and Compressive Strength (C) is $F = C^{0.42}$

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